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STUDIES ON PHASE AND MORPHOLOGY INVESTIGATION OF $BA_XSR_{1-X}TIO_3$ (X = 0.6, 0.70.8, AND 0.9) CERAMIC POWDERS

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ABSTRACT

This study aims to understand thoroughly the effects of calcining and sintering conditions on the relative permittivity and sintering behaviors of the solid solution method of preparing BSTs. BST ($Ba_xSr_{1-x}TiO_3$, x = 0.6, 0.7,0.8 and 0.9) was synthesized using an established solid-state reaction method [R.K. Roeder, E.B. Slamovich, Stoichiometry control and phase selection in hydrothermally derived $Ba_xSr_{1-x}TiO_3$ powders, J. Am. Ceram. Soc. 82 (7) (1999) 1655, R. Ganesh, E. Goo, Microstructure and dielectric characteristics of $Pb_xBa_{0.5-x}Sr_{0.5}TiO_3$ ceramics, J. Am. Ceram. Soc. 79 (1996) 225, J.W. Liou, B.S. Chiou, Effect of direct-current biasing on the dielectric properties of barium strontium titanate, J.Am. Ceram. Soc. 80 (12) (1997) 3093, T. Noh, S. Kim, C. Lee, Chemical preparation of barium–strontium titanate, Bull. Korean. Chem. Soc. 16 (1995) 1180]. From XRD, the tetragonal perovskite phase formation was confirmed. The lattice parameters a and c were calculated from the XRD data. As a function of frequency and temperature, the dielectric constant and dielectric loss were studied in the frequency range 1 kHz to 1 MHz. When the strontium content in the sample increases, unit cell volume decreases.

KEYWORDS: X-Ray Diffraction, Dielectric Constant, Dielectric Loss, Calcining, Sintering

INTRODUCTION

Ferroelectrics have become increasingly important as materials for electronic devices. The most widely used ferroelectrics occur in the perovskite family, with possess the general formula ABO_3 and are characterized by compounds such as barium titanate ($BaTiO_3$), strontium titanate ($SrTiO_3$) and barium strontium titanate (BST) [1,2]. Solid solutions of BST are commonly used as capacitors in dynamic random access memory (DRAM) because of the high charge storage density, low leakage current, and resistance vs. time dependent dielectric breakdown [3]. This study aims to understand variation of relative permittivity with strontium content variation in the BST. Specifically, X-ray diffraction is used to characterize the phase transition of calcined BST powders.

EXPERIMENT

Preparation of Samples

BST ($Ba_xSr_{1-x}TiO_3$, with x=0.1, 0.3, 0.5 and 0.7) was synthesized using a solid-state reaction method [4–7]. Reagent grade, $BaCO_3$, $SrCO_3$ and TiO_2 powders were used as starting materials. The powders were mixed by ball milling for 10h for uniform mixing. The mixed powders were calcined at 1100 to 1300^{0}C for 24h. After calcining the samples are ballmillied for 20h. Fine calcined powders were pressed into disc-shaped pellets at an isostatic pressure of10 tons. No binder was used. The pellets are sintered at 1200 to 1300^{0}C. To determine the dielectric properties, silver paste applied on both surfaces the sintered samples. The dielectric properties were measured using HOCI LCR HITESTER-3532-50 meter at 1 kHz –1 MHz from 300C to 2000C.

X-Ray Measurements

The powders were characterized by XRD diffract meter for crystal structure analysis.

Dielectric Measurements

The AC parameters such as capacitance (c) and dielectric loss of the samples were measured in the frequency range 1K Hz to 1MHz using LCR meter (HIOKI 3532-50 LCR Hi Tester). The variation of dielectric constant and dielectric loss with temperature were studied by recording the parameters at different frequencies (viz. 1 kHz, 10 kHz, and 100 kHz and 1 MHz). The dielectric constant (ε_r) was calculated using the relation:

$$\varepsilon_r = ct / (\varepsilon_o A)$$

Where c is the capacitance of the pellet, t the thickness of the pellet, A the area of cross section of the pellet and ε_o is the permittivity of free space (8.854×10^{-12} F/m).

RESULTS AND DISCUSSIONS

XRD pattern of calcined powders are shown in Figure 1. Variation of Lattice parameter with composition of x as shown in figure 2. Variation of Dielectric loss Vs temperature plot of BaxSr1-xTiO$_3$ at 1 kHz with composition of x as shown in figure 3. Variation of Dielectric constant Vs temperature plot of BaxSr1-xTiO$_3$ at 1 kHz with composition of x as shown in figure 4. The XRD pattern showed all major X-ray reflection peak of perovskite BST phase, indicating the polycrystalline nature of powder with (110) as the major peak. The variation of lattice constant, unit cell volume and average particle sizes with strontium content variation is shown in table 1. A small decrease in the unit cell volume takes place as the Sr content increases. The dielectric loss and variation dielectric constant with temperature is shown in figure 3 and 4 respectively.

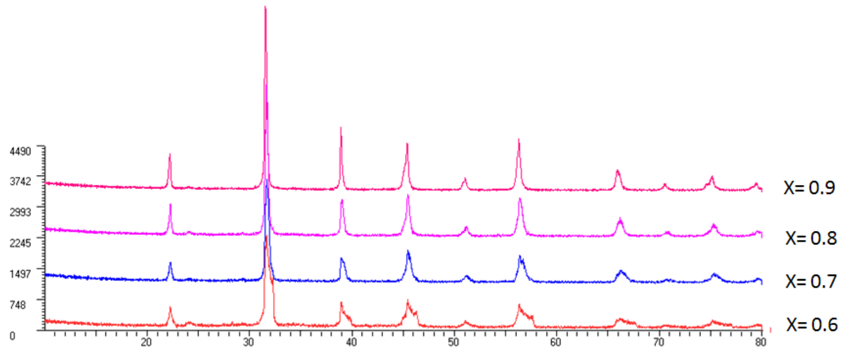

Figure 1: XRD Pattern of $Ba_xSr_{1-x}TiO_3$ for x = 0.6, 0.7, 0.8 and 0.9

Table 1: Data on Lattice Parameters, Unit Cell Volume and Particle Size

Com-Position X	Lattice Parameters			Unit Cell Volume	Average Particle Size (nm)
	a	c	c/a		
0.1	3.9109	3.9109	1	59.82	61.17
0.3	3.9320	3.9320	1	60.79	20.04
0.5	3.9539	3.9539	1	61.81	12.57
0.7	3.9830	4.0220	1.0097	62.58	17.18

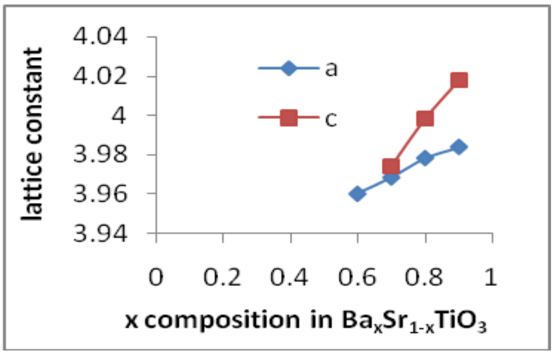

Figure 2: Lattice Constant Variation of $Ba_xSr_{1-x}TiO_3$

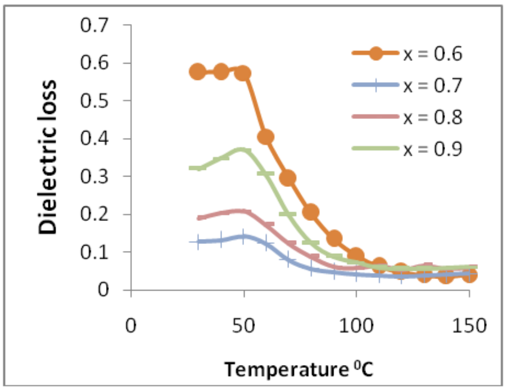

Figure 3: Dielectric Loss Vs Temperature Plot of $Ba_xSr_{1-x}TiO_3$ at 1 kHz

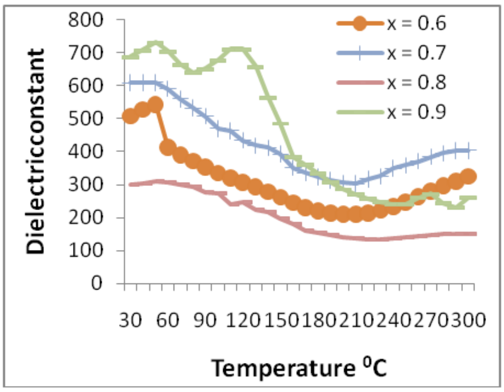

Figure 4: Dielectric Constant Vs Temperature Plot of $Ba_xSr_{1-x}TiO_3$ at 1 kHz

CONCLUSIONS

The result of lattice parameter measurements and XRD patterns conforms the perovskite phase transformation of the $Ba_xSr_{1-x}TiO_3$, x = 0.6, 0.7, 0.8 and 0.9 system. The unit cell volume was observed to increase slightly at higher x ratios. The lattice parameter of the unit cell was also observed to increase slightly with increasing x.

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